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MILITARY ANALYSI:

E. S. Quad

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MILITARY ANALYSIS

E. S. Quade

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PREFACE

This Memorandum surveys analysis as applied to national security problems. It was prepared as a lecture and delivered, in slightly abbreviated form, to the Air Command and Staff College on September 28, 1965.

SUMMARY

This Memorandum points out the need for the application of analytic techniques to military problems and for an understanding of these techniques by military officers. It defines systems analysis, describes its essential features, illustrates the process of analysis with examples, points out its virtues and limitations, and concludes with some remarks about its future.

MILITARY ANALYSIS

INTRODUCTION

Analytic techniques can be applied to military problems that range from routine day-by-day operations to critical decisions of national policy. It is essential for the military officer to know something about the capabilities and limitations of such techniques, as he may be assigned to sponsor, evaluate, implement, or even take part in studies where they are applied.

Military analysis takes its most mathematical—and, in a certain sense, its most fruitful—role when applied to the peacetime housekeeping operations of the armed forces. In this context, the analysis differs little from that concerned with decisionmaking and resource allocation in commerce and industry: stock control, personnel assignment, reliability checkout, transportation routing, and so forth. It is management science—or operations research in the strict sense—an attempt to increase the efficiency of a man-machine system in a situation where it is clear what "more efficient" means. Characteristically, problems of this type are so well-structured that contributions to management decisions can be reduced to the application of systematic computational routines to a generic "model" which, by a specification of its parameters, can be made relevant to a wide variety of operations. The queuing model, for example, is relevant to many aspects of the operations of communication systems, airfields, service facilities, maintenance shops, and so on.

The true military analysis, however, involves some element of conflict. This implies more than competition in the business sense. Thus, communication by transoceanic cable may compete with communication by satellite, but there is no need to worry about the supplier of one service

attemptimg to jam the service of the other. Problems such as whether to employ aircraft or artillery to knock out a defended point or how to allocate a missile payload between warhead, decoys, and protection belong in this conflict category. The major impetus to the development of techniques to handle problems of this type was provided early in World War II by the introduction of new weapons and weapon systems (radar is the outstanding example) so novel in concept and design that their exploitation could not be planned purely on the basis of traditional military experience. The questions addressed were largely tactical: how to introduce "window" or "chaff" as a radar countermeasure; how to determine more effective bombing patterns; how to determine better antisubmarine search procedures; or how to deploy destroyers to best protect a convoy. New methods of analysis had to be developed. These formed the beginnings of a body of knowledge called at that time "operations analysis" and later, in various extensions, "operations research," "systems engineering," "management science," "cost-effectiveness analysis," or "systems analysis." Depending on the context, and, to different people, they might imply some subtle distinction. The term "systems analysis," for example, came into use because the first postwar efforts dealt with the selection and optimization of weapon systems. The new name was needed to suggest that we were no longer necessarily dealing with current operations for which the inputs were largely known, the objectives clear, and the uncertainties limited.

But all these terms convey the same general meaning. Moreover, there exist between them no distinctions in principle. Whatever differences may be found are simply matters of degree, emphasis, and context. However, the characteristics they have in common <u>are</u> important: an effort to make comparisons systematically and in quantitative terms, the use of a logical sequence of steps that can be retraced and verified or modified by others.

Some fifteen years ago weapons systems analysts (particularly at The RAND Corporation) began an attempt to include the formulation of national security policy and strategy as part of their field of interest. The initial reactions of experienced "military analysts," in the Pentagon and elsewhere were (1) that the nature of military policy and of national security problems was quite different from operations analysis or the weapons systems optimization and selection in which RAND and these analysts had been reasonably successful and (2) that the tools, techniques, and concepts would not carry over. Strategy and policy planning were arts, and would remain so.

Fortunately, these skeptics were only partially right. It is true that additional concepts and methodologies significantly different from those of earlier analysis had to be developed. But there has been large transfer and substantial progress. In fact, the years since 1961 have seen a marked increase in the extent to which analyses of strategic policy have influenced decisionmakers on the broadest issues of national security.

In its research for the United States Air Force, The RAND Corporation has played a leading role in developing an approach to the full range of defense problems, an approach that RAND calls "systems analysis." In the following discussion, we hope to make clear the nature and scope of this analysis, to give some idea of its methods and procedures, to discuss its problems and limitations, and to indicate why it is useful.

DEFINITIONS

What is systems analysis? Speaking loosely, any analytic study designed to help a decisionmaker identify a preferred choice from among possible alternatives might be termed a systems analysis. In a military context,

typical analyses might tackle such problems as (1) the extent to which aircraft should be repaired at a depot rather than on the base, (2) the possible characteristics of a new strategic bomber and whether one should be developed, (3) whether tactical air wings, carrier task forces, or neither should be substituted for U.S. ground divisions in Europe, or (4) whether we should modify the test ban treaty now that the Chicoms have nuclear weapons —and, if so, how.

Every such analysis involves, as one stage, a comparison of alternative courses of action in terms of their costs and their effectiveness in attaining a specified objective. Usually this comparison takes the form of an attempt to minimize the cost implications of choosing each alternative subject to some mission requirement (which in national security problems is unlikely to be measurable in dollar terms) or, conversely, to maximize some physical measure of performance subject to a budget constraint. Since such comparisons often receive the lion's share of attention by the participants, studies of this type are frequently called cost-effectiveness analyses. But this name puts too much emphasis on costs. In an analysis designed to furnish advice on military policy, other facets of the problem may be of greater significance: the specification of sensible objectives, the determination of a satisfactory way to measure performance, the influence of considerations that cannot be quantified, or the discovery of adequate alternatives.

This last point can best be illustrated by a simple example.

Suppose a family has decided to buy a television set. Not only is their objective fairly clear, but, if they have paid due attention to the advertisements, their alternatives are well defined. The situation is then one for cost-effectiveness analysis. The only significant questions

concern the differences in performance and cost among the available sets. With a little care, making proper allowance for financing, depreciation, and maintenance, the family can estimate, say, the five-year procurement and operating cost of any particular set. They will discover, of course, that finding a standard for measuring the performance of the various sets is somewhat more difficult. For one thing, it may have many aspects—they must consider color quality, the option for remote control, portability, screen size, and so forth. But, ordinarily, one consideration—perhaps color—determines a price class. On this basis, they can look at some color sets, compare costs against color quality, and finally determine a best buy.

Now, suppose the family finds they have more money to spend and thus decide they can increase their standard of living—a decision similar to one to strengthen the U.S. defense posture by raising the military budget. This is a situation for systems analysis. They first need to investigate their goals or objectives and look into the full range of alternatives—a third car, a piano, a country club membership. They then need to find ways to measure how well these alternatives accomplish their goals and establish criteria for choice among them. Here, because the alternatives are so dissimilar, determining what they want to do is the major problem; how to do it and how to determine what it costs may become a comparatively minor one.

In brief, to qualify as a complete systems analysis a study must look at the entire problem and look at it in its proper context. Characteristically, such an analysis will involve a systematic investigation of the decision-maker's objectives and of the relevant criteria; a comparison—quantitative where possible—of the cost, effectiveness, risk, and timing associated with each

alternative policy or strategy for achieving the objectives; and an attempt to formulate better alternatives if those examined are found wanting. In fact, in the light of these costs and alternatives, objectives more realizable than the original ones may have to be formulated.

THE ESSENCE OF THE METHOD

What is there about an analytic approach that makes it better or more useful than other ways to furnish advice —than, say, an expert or a committee? In areas such as defense planning, where there is no accepted theoretical foundation, advice obtained from experts working individually or as a committee depends largely on judgment and intuition. So does the advice from systems analysis. But the virtue of such analysis is that it permits the judgment and intuition of experts in many fields to be combined to yield results transcending those of any ordinary individual or committee. The essence of the method is to construct and operate within a "model"—a simplified abstraction of the real situation appropriate to the question. Such a model—which may take such varied forms as a computer simulation, a war game, or even a purely verbal "scenario" —introduces a precise structure and terminology that serve primarily as a means of communication, enabling the participants in the study to exercise their judgment and intuition in a concrete context and in proper relation to that of others. Moreover, through feedback (the results of computation, the countermoves in the war game, or the critique of the scenario) the model helps the experts to revise their earlier judgments and thus to arrive at a clearer understanding of the problem and its context.

The central importance of the model can be seen most readily, perhaps, by looking at its relation to the other elements of analysis. There are five altogether, and each is present in every analysis of choice, although not always explicitly identified.

1. <u>The objective (or objectives)</u>. Systems analysis is undertaken primarily to help choose a policy or course of action. The first and most important task of the analyst is to discover what the decisionmaker's objectives are (or should be) and how to tell the extent to which they are, in fact, attained by various actions. This done, strategies, forces, or equipment are examined, compared, and recommended on the basis of how well and how cheaply they can accomplish these objectives.

2. <u>The alternatives</u>. The alternatives are the means by which it is hoped the objectives can be attained. They need not be obvious substitutes for one another or perform the same specific function. Thus, shelters, "shooting" defenses, a counterforce capability, and retaliatory striking power are all alternatives in protecting civilians against air attack.

3. <u>The costs</u>. The choice of a particular alternative for accomplishing the objectives implies that certain specific resources can no longer be used for other purposes. These are the costs. In analyses for a future time period, most costs can be measured in money, but their true measure is in terms of the opportunities that they preclude. Thus, if we are comparing ways to suppress guerrillas, the damage to nonparticipants caused by the various alternatives must be considered a cost, for such damage may recruit more guerrillas.

4. <u>A model (or models)</u>. A model is a simplified, stylized representation of the real world which abstracts the cause-and-effect relationships essential to the question studied. The means of representation may range from a set of mathematical equations or a computer program to a purely verbal description of the situation, in which intuition alone is used to predict the consequences of various choices. In systems analysis (or any analysis of choice), the role of the model (or models, for it may be

inappropriate or absurd to attempt to incorporate all the aspects of a problem in a single formulation) is to estimate for each alternative the costs that would be incurred and the extent to which the objectives would be attained. This requires a measure of effectiveness or means for indicating the degree of achievement for each goal.

5. A criterion. A criterion is a rule or standard by which to rank the alternatives in order of desirability and to choose the most promising. It provides a means for weighing cost against effectiveness.

As illustrations of how these elements of analysis enter into decision problems, let us consider two examples.

A NARROW EXAMPLE: SELECTION OF A NEW AIRCRAFT ENGINE

As an example* of how the elements of analysis figure in a relatively narrow decision problem, consider the selection of a new aircraft engine. The objective may be simply to obtain increased engine performance. Then the alternatives are the various possible engine types that offer a chance of achieving this objective by such means as exotic fuels or novel design. The costs would be of two general kinds: the total capital resources (such as manpower and facilities) that must be allocated to the research and development and the time required to obtain a successful prototype. In this case, the measure of effectiveness might be taken as the difference between the specific fuel consumption typical today and that achieved by further research, for fixed engine weight. In general, the amount of improvement will depend on the amount of effort expended for research and preliminary development, so that the costs and effectiveness, estimated by means of various models, might be related as in Fig. 1. These

*This approach was suggested by Lee Attaway of RAND.

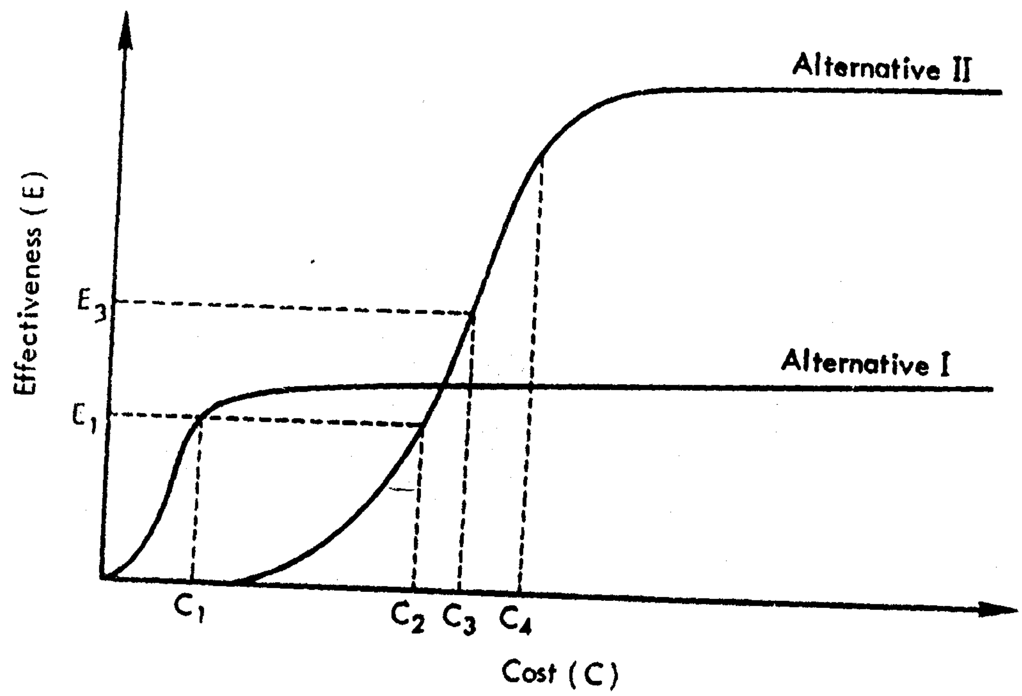

Fig. 1—Cost and effectiveness

models might consist of such devices as standard engineering formulas, extrapolations from curves fitted to empirical data, or even guess-estimates from propulsion engineers.

Such different levels of performance might result from a situation in which alternative I corresponds to a very conservative improvement over operational engines, and alternative II, to a larger state-of-the-art advance.

Note, however, that even if we assume that both these alternative research programs can be completed on time and are subject to essentially the same amount of uncertainty, we still could not decide between them. We have not as yet specified the <u>criterion</u> or rule for choice. What is missing is some knowledge of why the improved performance is needed. Thus, although alternative I achieves only a modest level of effectiveness (E_1), it does so at one-third the cost of alternative II. If the level E_1 is adequate, why not select alternative I and thereby minimize cost? Indeed, quite often cost will be limited by decree to some level such as C_2, in which case alternative I is the obvious choice. On the other hand, the goal of the research may be to achieve some minimal new level of effectiveness, such as E_3, no matter what the cost. Then alternative II is obviously the choice.

Generally it is impossible to select between two alternatives just on the basis of the cost and effectiveness data shown in the figure. Usually, either a required effectiveness must be specified and then the cost minimized for that effectiveness, or a required cost must be specified and the effectiveness maximized. Clearly, the results of the analysis of effectiveness should influence the selection of the final criterion. For example, if C_3 is truly a reasonable cost to pay, then the case for C_4 is much stronger, in veiw of the great gains to be made for a relatively small additional investment. As a matter of fact, this approach of setting maximum cost so that it

corresponds to the knee of the cost-effectiveness curve is a very useful and prevalent one, since very little additional effectiveness is gained by further investment.

Not let us look at an example which involves the treatment of conflict.

A BROADER EXAMPLE: DEFENSE OF A MISSILE FORCE

Consider the question of whether or not to buy active defense for a land-based ICBM force. It is obvious without analysis that if ICBM's are expensive and it is possible to defend them cheaply and efficiently, then, if there is an appreciable danger of attack, we should buy a defense system. But just how expensive? How efficient? Let us attempt to indicate the points to consider in this problem.

Let us take deterrence as the objective in considering the addition of a defense system. As the measure of effectiveness for attainment of this objective the number of operationally ready missiles surviving an enemy first strike seems a reasonable choice. The relevant alternatives are the various means of providing active defense. Of course, providing no defense at all and using the budget for it to buy additional missiles is one alternative.

As a first approximation, the costs can be the dollar costs to maintain the force we have plus the costs of augmenting it either with additional missiles or with a defense.

Since we have no idea how many surviving missiles are needed to attain the objective but may have a fair idea of how much money Congress is likely to make available for this purpose, let us take the approach of fixing the budget level and seeking to maximize effectiveness.

To carry on from here, a series of models are needed to work out what the various costs and strike outcomes might be. Then, finally, a criterion is needed to weigh the war outcomes and determine a preference ordering of the alternatives. For this, the rule might be to select the alternative which for the fixed budget gives the maximum number of surviving missiles.

First, to begin the analysis the forces obtainable with the budget must be worked out. This is not necessarily a simple task. A budget bears a specific date and time factors are important. The cost model must not only measure the purchase price of the various weapons, vehicles, buildings and materiel and manpower structure, but also take into account the entire system of utilization, extended over a period of time prolonged sufficiently to reflect the important factors of peacetime operations and maintenance. To do this properly the resource impact on the full force structure must be estimated.

Second, for some representative range of contingencies the environment and mode of war initiation must be specified. Here a set of scenarios that show how, starting with the present state of the world, future situations might evolve and how in these situations war might begin is almost essential.

Third, usually through a step-by-step procedure which simulates the course of an enemy strike, a campaign model which works out the various strike outcomes must be constructed. This model should estimate for us, under various assumptions about what action the enemy may take, the state of the world, the capabilities of our defense weapons, and so forth, the number of missiles to survive the enemy attack. The model should take into account such considerations as strength of the attack, probability that an undefended missile survives an enemy shot, probability that a defending missile destroys an attacking missile, effect of saturation, and electronic countermeasures. It must reflect the various tradeoffs between such items as the accuracy and yield of the attacking missiles, the hardness of sites, and the range and state of readiness of the defending missiles. To do this it may have to be a hierarchy of many models.

For instance, a submodel will be required to study how the probability of one of our missiles being destroyed

depends on such factors as the attacker's accuracy, the size of his warheads, and the hardness of our sites.

Finally, we may arrive at some results and we may still have a problem. For example, we may have something like the following:

Contingency	Number of Surviving Missiles		
	Alt. A	Alt. B	Alt. C
1	70	110	130
2	75	120	80
3	120	100	50
4	130	120	90

Choice among the alternatives thus depends on the likelihood of the various contingencies.

Actually, however, choice among them is not the full story. We set out to recommend the alternative that would lead to the largest number of surviving missiles. This, by itself, is not adequate. Suppose, for example, costs, scale of attack, and kill probabilities lead to the conclusion that a small defended missile force is preferable to a larger undefended force because it has more surviving missiles. But further suppose that in neither case the force survives in sufficient strength to be useful. Then we must look for other and more satisfactory alternatives --possibly sea-based or mobile missiles.

A process such as this is necessarily incomplete. Many considerations have not been mentioned, among them the possibility of grouping the ICBM's to share defense; a policy for the attacker that involves some form of reconnaissance during the attack; the possibility that the defense may protect other targets. To take enemy actions

into account properly we may need to bring game theory considerations into the model. Chance effects and fluctuation may be important also; a single number (say, the expected number) may not provide an adequate comparison. The range of possibilities may be important; to take that into account the model may have to be a Monte Carlo one in which fluctuation is treated by drawing random samples from carefully determined distributions.

Finally, there are the intangibles; for example, the values, military and political, that may come just from owning a larger missile force, apart from survivial in the attacks considered, or the value of having a defense, even though inefficient, that may boost civilian morale.

THE PROCESS OF ANALYSIS

Having formulated and researched the problem—that is, clarified the issues, limited the extent of the inquiry, searched out the necessary data and relationships, identified the various elements and built the models—the process of analysis may be outlined as follows. (See Fig. 2.) To begin, the various alternatives (which may have to be discovered or invented as part of the analysis) are examined by means of the models. These models tell us what we can expect from each particular alternative with respect to such things as attrition, targets destroyed, and so forth, and what the costs are. The measures of effectiveness tell us the extent to which each objective is attained. A criterion can then be used to weigh the costs against performance and thus arrange the alternatives in order of preference.

This process may break down at almost any stage. Some problems are so ill structured and the cause-and-effect relationships so poorly understood that we cannot with any feeling of confidence set up a model that will predict the consequences of choosing an alternative.

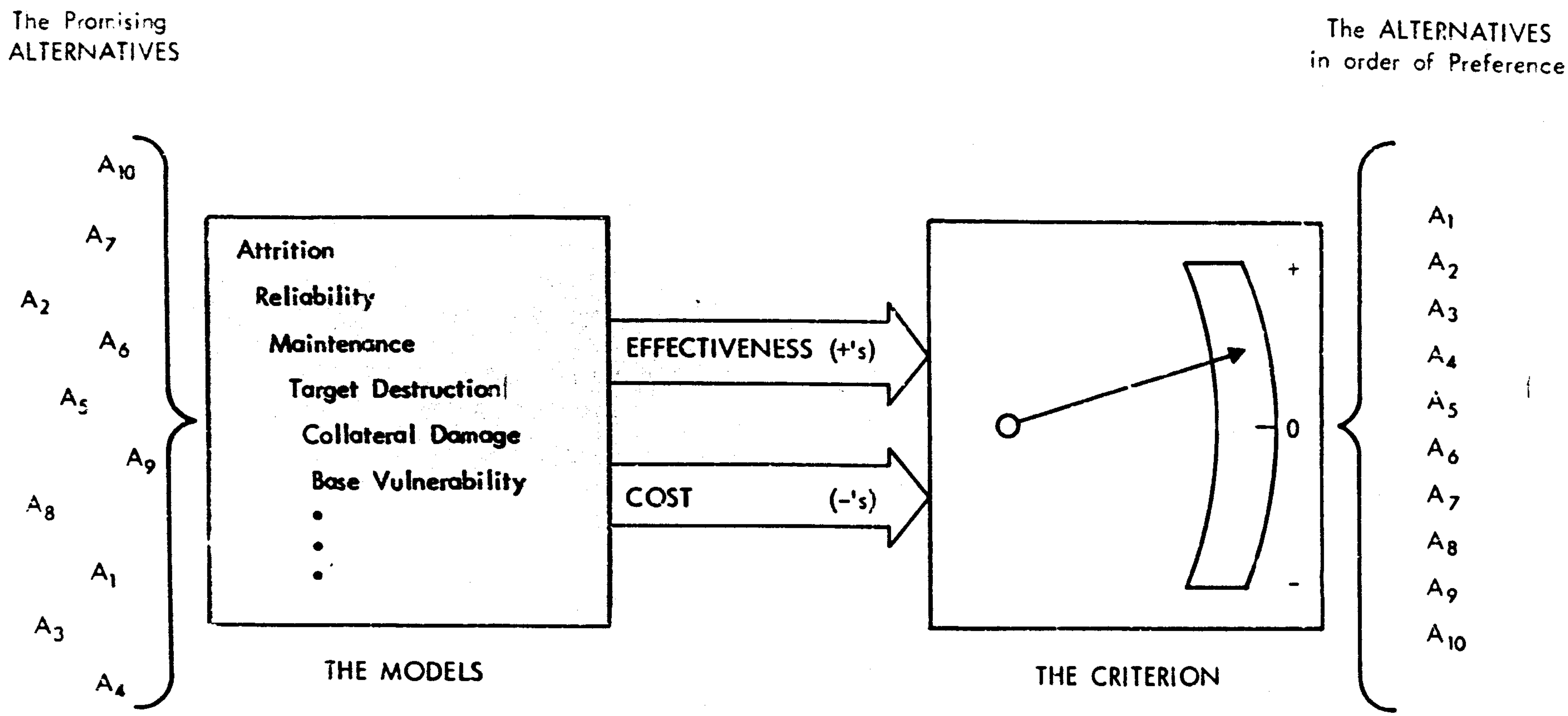

Fig. 2—The structure of analysis

If we cannot work out the consequences of adopting the various strategies, we cannot compare outcomes. The alternative is then the far less satisfactory one of using a model that compares the salient characteristics of the possible strategies. This is the "consumers' research" approach, in which experts or "potential users" rate the alternatives. Again, of course, some way is needed to bring the various ratings together—a problem that has already come up in comparing alternatives for different contingencies.

In these situations, judgment must be employed to reach a decision. Expert opinion can be called on when it is necessary to use numerical data or assumptions that cannot be based on theory or experience—when, say, we want to obtain something like an estimate of the guidance accuracy of our new missile in the presence of counter-measures that have been conceived in theory but have not yet been developed. When values are involved, we may follow the same procedure.

Ordinarily, we would like to employ the judgment of more than one expert. Even though their advice usually differs, there are several ways to try for a consensus from several experts. The traditional way has been to assemble them in one place, to let them discuss the problem freely, and to require that they arrive at a joint answer. They could also be put to work individually, letting others seek methods for the best combined use of their findings. Or they could be asked to work jointly in a group exercise—ranging from a simple structured discussion to a sophisticated simulation—to obtain judgments from the group as a whole.

Another method, falling somewhere between individual and group action, attempts to improve the panel or committee approach by subjecting the views of the individual experts to each other's criticism without actual

confrontation and all its psychological shortcomings. Direct debate is replaced by a carefully designed sequence of individual interrogations (possibly conducted by questionnaires). At each step, the participants are given new or refined information and opinion feedback is derived by computed consensus from the earlier part of the program. The process continues until either a consensus is reached or the conflicting views are documented fully.

It should be emphasized that in many important problems it is not possible to build really quantitative models. The primary function of a model is "explanatory," to organize our thinking. The essence of systems analysis is not mathematical techniques or procedures, and its recommendations need not follow from computation. Thus, a computing machine or a technique such as dynamic programming may or may not be useful, depending on the problem and the extent to which quantification is possible. What counts is the effort to compare alternatives systematically, in quantitative terms when possible, using a logical sequence of steps that can be retraced and verified by others.

Usually, we can go beyond the bare minimum, and although we may not be able, initially, to abstract the situation to a mathematical model or series of equations, some way can generally be found to represent the consequences that follow from particular choices. Simulation can often be used to tackle seemingly unmanageable or previously untouched problems where a traditional analytic formulation first appears infeasible. For example, a computer routine may be used to represent the essential features of a system by means of random numbers and its behavior analyzed by operating with the representation case-by-case. Operational gaming—that is to say, simulation involving role-playing by the participants—is another particularly promising technique, especially when it is desirable to employ several experts with varying

specialties for different aspects of the problem. Here the game structure—again a model—furnishes the participants with an artificial, simulated environment within which they can jointly and simultaneously experiment, acquiring through feedback the insights necessary to make successful predictions within the gaming context and thus indirectly about the real world.

Unfortunately, things are seldom tidy: Too often alternatives are not adequate to attain the objectives; the measures of effectiveness do not really measure the extent to which the objectives are attained; the predictions from the model are full of uncertainties; and other criteria which look almost as attractive as the one chosen may lead to a different order of preference. When this happens, no one is satisfied with the results and we must take another approach. A single attempt or pass at a problem is seldom enough. (See Fig. 3.) The key to successful analysis is a continuous cycle of formulating the problem, selecting the objectives, designing better alternatives, collecting data, building new models, weighing cost against performance, testing for sensitivity, questioning assumptions and data, reexamining the objectives, opening new alternatives, and so on until satisfaction is obtained or time or money forces a cutoff.

THE VIRTUES

In stating the purpose of systems analysis, we have, in a sense, said what it can do. It can be applied to a range of problems extending from the very narrow to the very broad. At one end of the range, it may help to determine how much of the Air Force construction budget should be allocated to hangars, or whether the electrical maintenance shop should be amalgamated with some other shop, or what type of all-weather landing system should be installed in a new transport aircraft. At the other

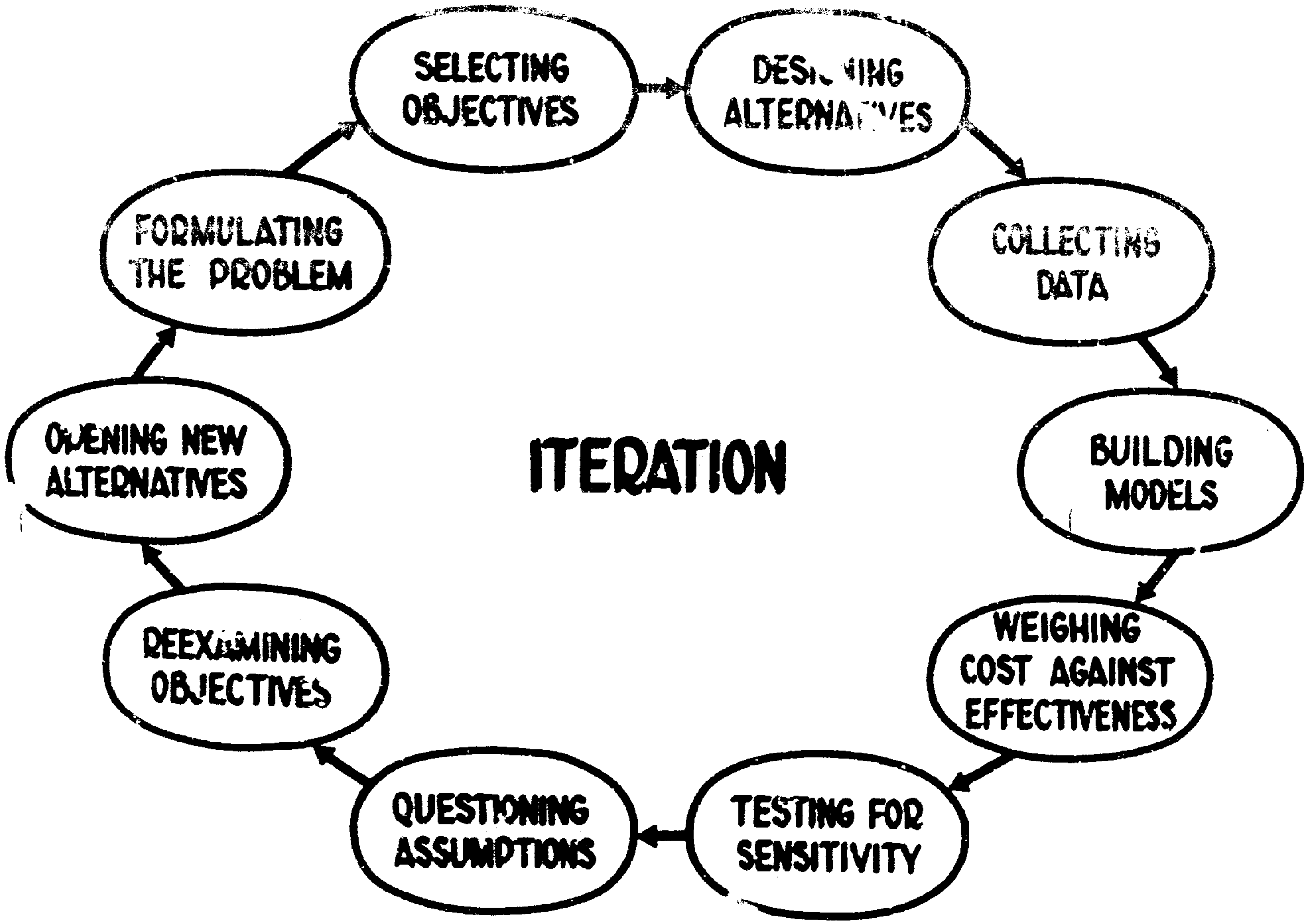

Fig. 3—The key to analysis

end, it can help to decide how much should be spent on national defense, or how the defense budget should be allocated between strategic and general-purpose forces, or whether the additional capability provided by a tactical air wing would be worth its cost.

Analysis is essential. Without calculation there is no way to discover how many missiles may be needed to destroy a target system, or how arms control may affect security. Analysis offers an alternative to "muddling through"; to waiting until one can see the problem clearly and then attempting to meet the situation. Delay can be hazardous; in the world today, there could be a crisis or a weapon that could not be handled in this way. This is not to say that every aspect of military problems can be quantified or that analysis is without limitations, but only that it is not sensible to formulate national defense policy without careful consideration of whatever relevant numbers can be discovered.

It is easy, unfortunately, to exaggerate the degree of assistance that systems analysis can offer the policy-maker. In almost every case, it can help him understand the relevant alternatives and the key interactions by providing an estimate of the costs, risks, and possible payoffs associated with each course of action. It may sharpen his intuition and will certainly broaden his basis for judgment, thus helping him make a better decision. But value judgments, imprecise knowledge, intuitive estimates of enemy intent, and other difficulties mean that a study can do little more than assess some of the implications of choosing one alternative over another. In practically no case, therefore, should the decision-maker expect the analysis to demonstrate that, beyond all reasonable doubt, a particular course of action is best.

THE LIMITATIONS

Every systems analysis has defects. Some of these are limitations inherent in all analysis of choice. Others are a consequence of the difficulties encountered in coping with such factors as uncertainty about the enemy or the varying times at which alternatives become available. Still others are blunders or errors in thinking which, hopefully, will disappear as we learn to do better and more complete analyses.

The alternatives to analysis also have their defects. One alternative is pure intuition. It is in no sense analytic, since no effort is made to structure the problem or to establish cause-and-effect relationships and operate on them to arrive at a solution. The process is to learn everything possible about the problem, to "live with it," and to let the subconscious provide the solution.

Between pure intuition, on the one hand, and systems analysis, on the other, other sources of advice can, in a sense, be considered to employ analysis, although ordinarily a less systematic, explicit, and quantitative kind. One alternative is to turn to an expert. His opinion can, in fact, be very helpful it if results from a reasonable and impartial examination of the facts, with due allowance for uncertainty, and if his assumptions and chain of logic are made explicit. Only then can others use his information to form their own considered opinion. But an expert, particularly an unbiased expert, may be hard to find.

Another way to handle a problem is to turn it over to a committee. Committees, however, are much less likely than experts to make their reasoning explicit, since their findings are usually obtained by bargaining. This is not to imply that a look by a "blue ribbon" committee into our missile defense problem might not be useful, but its greatest utility is likely to be in the critique of work done by others.

However, no matter whether the advice is supplied by an expert, a committee, or a formal study group, the analysis of a problem of choice involves the same five elements and basic structure we mentioned earlier.

It is important to remember that all analysis of choice falls short of scientific research. No matter how we strive to maintain standards of scientific inquiry or how closely we attempt to follow scientific methods, we cannot turn military analysis into science. Its objective, in contrast to that of science, is primarily to recommend—or at least to suggest—policy, rather than merely to understand and predict. Like engineering, it seeks to use the results of science to do things well and cheaply. Yet, when applied to national security problems, it differs from ordinary engineering in its enormous responsibility, in the unusual difficulty of appraising—or even discovering—a value system applicable to its problems, and in the absence of ways to test its validity.

Except for this inability to verify, systems analysis may still look like a purely rational approach to decision-making, a coldly objective, scientific method free of preconceived ideas and partisan bias and judgment and intuition.

It isn't, really. Judgment and intuition are used in designing the models; in deciding what alternatives to consider, what factors are relevant, what the inter-relations between these factors are, and what criteria to choose; and in analyzing and interpreting the results of the analysis. This fact—that judgment and intuition permeate all analysis—should be remembered when we examine the apparently precise results that come from analysis.

Many flaws are the results of pitfalls faced by the analyst. He may emphasize the model instead of the

question, or concentrate on the type of uncertainty that can be treated analytically by Monte Carlo or other statistical techniques rather than on the real uncertainties, or neglect elements that cannot be handled quantitatively.

There are also pitfalls for the officer who commissions or acts on a study. For instance, he must not specify assumptions and limit the problem arbitrarily. When a problem is first observed in one part of a military organization, there is a tendency to seek a solution completely contained in that part. An administrator is thus likely to pose his problems in such a way as to bar from consideration alternatives or criteria that do not fit into the chain of steps by which policy has been made in past years in the field in question. Also, to act wisely on the basis of someone else's analysis one should, at the very least, understand the important and fundamental principles involved. One danger associated with analysis is that it may be employed by an administrator who is unaware of or unwilling to accept its limitations.

The most dangerous pitfall or source of defects is the attention bias. It is frequently caused by a cherished belief or an unconscious adherence to a "party line." All organizations foster one to some extent; RAND, the military services, and the DOD are no exception. My feeling is that Herman Kahn was right when he called the party line "the most important single reason for the tremendous miscalculations that are made in foreseeing and preparing for technical advances or changes in the strategic situation."* Examples of an attention bias are plentiful: the military planner whose aim is so fixed on "winning" local wars that he excludes other considerations, or so fixed on maximizing

*H. Kahn and I. Mann, Ten Common Pitfalls, The RAND Corporation, RM-1937, July 17, 1957, p. 42.

deterrence that he completely disregards what might happen should deterrence fail; the weaponeer who is so fascinated by startling new weapons that he assumes they will, of course, be used; the State Department negotiator who seeks to conciliate the potential enemey at a military cost that is far too great, because he is unaware of it. In fact, this failure to realize the vital interdependence among political purpose, diplomacy, military posture, economics, and technical feasibility is the typical flaw in most practitioners' approach to national security analysis.

Pitfalls are one thing, and the inherent limitations of analysis itself another. These limitations confine analysis to an advisory role. Three are commented on here: analysis is necessarily incomplete; measures of effectiveness are inevitably approximate; and ways to predict the future are lacking.

Analysis Is Necessarily Incomplete

Time and money costs obviously place sharp limits on how far any inquiry can be carried. The very fact that time moves on means that a correct choice at a given time may soon be outdated by events and that goals set down at the start may not be final. The need for reporting almost always forces a cutoff. This is particularly important in military analysis, for the decision-maker can wait only so long for an answer. Other costs of inquiry are important here, too. For instance, we would like to find out what the Chicoms would do if we put an end to all military aid to Southeast Asia. One way to get this information would be to stop such aid. But while this would clearly be cheap in immediate dollars, the likelihood of other costs later precludes this type of investigation.

Still more important, however, it the general fact that, even with no limitations of time and money, analysis

can never treat all the considerations that may be relevant. Some are too intangible—for example, how some unilateral U.S. action will affect NATO solidarity or whether Congress will accept military economies that disrupt cherished institutions such as the National Guard or radically change the pattern of domestic military spending. Considerations of this type can, and possibly should, play as important a role in the choice of alternative force postures as any idealized war outcome calculations. But ways to measure them, even approximately, don't exist today, and they must be handled intuitively. Others involve moral judgments—for example, whether national security is better served by an increase in the budget for defense or for welfare, or under what circumstances is the preservation of an ally worth the risk of general war. The analyst can apply his a. ' others judgment and intuition to these considerations, thus making them part of the study and bringing them to the attention of the decisionmaker, but the man with the responsibility will rightly insist on applying his own.

Measures of Effectiveness Are Approximate

In military comparisons measures of effectiveness are at best reasonably satisfactory approximations for indicating the attainment of such vaguely defined objectives as deterrence or victory. Sometimes the best that can be done is to find measures that point in the right direction. Consider deterrence, for instance. It exists only in the mind—and in the enemy's mind at that. We cannot, therefore, measure the effectiveness of alternatives we hope will lead to deterrence by some scale of deterrence, but must use instead such approximations as the potential mortalities that we might inflict or the roof cover we might destroy. Consequently, even if a comparison of two systems indicated that one could inflict 50 percent more casualties on the

enemy than the other, we could not conclude that this means the system supplies 50 percent more deterrence. In fact, since in some circumstances it may be important not to look too dangerous, we find arguments that the system threatening the greatest number of casualties may provide the least deterrence!

Moreover, we can't be as confident about the accuracy of our estimates of effectiveness as we are about our cost estimates. For example, one analyst who is studying the problem of estimating casualties with current weapons believes that a pre-World War II estimator even if he had worked with the same sophistication as his brother of today, had known his trade exceptionally well, had been knowledgeable about the means by which World War II military actions produced casualties, had known the probabilities associated with each weapon, and could have estimated the number of people at risk—then such an estimator would still have underestimated the total cost in human lives of the war to the Soviets by a factor of between three and four!

Such an error in the measurement of effectiveness may not be too important if we are comparing two not radically unlike systems—two ground attack aircraft, say. But at higher levels of optimization—tanks versus aircraft or missiles—gross differences in system effectiveness may be obscured by gross differences in the quality of damage assessment.

In brief, we don't know how to translate a capability to create casualties (as perceived by the enemy) into deterrence, we don't know how they enemy will assess the casualty-producing potential of our forces, and we don't even know how to compute it ourselves very accurately.

On the other hand, this does not mean that the determination of the dollar costs of a military action is simple. It takes know-how and research to estimate the

costs of weapons and forces that are as yet only concepts. But with care and experience, once we decide <u>what</u> we are costing, we can do fairly well.

No Satisfactory Way to Predict the Future Exists

While it is possible to forecast events to come in the sense of mapping out possible futures, there is no satisfactory way to predict a single future in terms of which we can work out the best system or determine an optimum policy. Consequently, we must consider a range of possible futures or contingencies. In any one of these we may be able to designate a preferred course of action, but we have no way to determine one for the entire range of possibilities. We can design a force structure for a particular war in a particular place, but we have no surefire way to work out a structure that is good for the entire spectrum of future wars in all the places they may occur.

Consequently, defense planning is rich in the kind of analysis that tells what damage could be done to the United States given a particular enemy force structure (or, to put it another way, what the enemy requirements would be to achieve a given destruction); but it is poor in the kinds of analyses that evaluate how we will actually stand in relation to the Soviets in years to come.

In spite of their limitations, quantitative estimates of costs and effectiveness are clearly helpful to any intelligent discussion of national security. In current Department of Defense practice these quantitative estimates are used extensively. Many people, however, are vaguely uneasy about the particular way these estimates are made and their increasingly important role in military planning.

For example, an Air Force officer* writes that computer-oriented planning techniques are dangerous; that mathematical models of future wars are inadequate for defense planning; and that scientific methods cannot handle those acts of will which determine the conduct of war. A Senator** remarks, "Our potential enemies may not use the same cost-effectiveness criteria and thus oppose us with the best weapons their technology can provide. This would create an intolerable peril to the national security."

Some skepticism may be justified, for the work may not always be competently done or used with its limitations in mind. There may indeed be some dangers in relying on systems analysis, or on any similar approach to broad decisions. For one thing, since many factors fundamental to problems of national security are not readily amenable to quantitative treatment, they may possible be neglected, or deliberately set aside for later consideration and then forgotten, or improperly weighed in the analysis itself or in the decision based on such analysis. For another, a study may, on the surface, appear so scientific and quantitative that it may be assigned a validity not justified by the many subjective judgments involved. In other words, we may be so mesmerized by the beauty and precision of the numbers that we overlook the simplifications made to achieve this precision, neglect analysis of the qualitative factors, and overemphasize the importance of idealized calculations in the decision process. But without analysis we face even greater dangers in neglect of

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*Colonel Francis X. Kane, USAF, "Security Is Too Important To Be Left to Computers," Fortune, Vol. 69, No. 4, April 1964.

**Senator John O. Pastore of Rhode Island, quoted in U.S. News and World Report, January 6, 1964.

considerations and in the assignment of improper weights! And better analysis and careful attention to where analysis ends and judgment begins should help reduce these dangers.

THE FUTURE

And finally, what of the future? Resistance by the military to the use of systems analysis in broad problems of strategy is gradually breaking down. Military planning and strategy have always involved more art than science; what is happening is that the art form is changing from an ad hoc, seat-of-the-pants approach based on intuition to one based on analysis supported by intuition and experience. With this change the computer is becoming increasingly significant—as an automaton, a process controller, an information processor, and a decision aid. Its usefulness in serving these ends can be expected to grow. But at the same time, it is important to note that even the best computer is no more than a tool to expedite analysis. Those advocates who hold that national defense decisions can be made today solely by consideration of computer calculations are not only premature in their belief (to say the least), but have a basic misunderstanding of how such calculations must, in fact, always be used. Even in the narrowest military decisions, considerations not subject to any sort of quantitative analysis can always be present. Big decisions, therefore, cannot be the automatic consequence of a computer program or of any application of mathematical models.

For broad studies, involving force posture and composition or the strategy to achieve foreign policy objectives, intuitive, subjective, even ad hoc study schemes must continue to be used—but supplemented to an increasing extent by systems analysis. The ingredients of analysis must include not only an increasing use of computer-based analysis for those problems where it is

appropriate, but also for treatment of the nonquantifiable aspects, a greater use of techniques for better employment of judgment, intuition, and experience. These techniques —war gaming, "scenario" writing, and the systematic interrogation of experts—are on the way to becoming an integral part of military analysis.

Moreover, the scope will broaden. Systems analysis has barely entered the domain of the social sciences. Here, in urban planning, in education, in welfare, and in other nonmilitary aspects of government we are faced with an abundance of challenges. Systems analysis can help with the problems there,* as well as with those of industry and national defense.

CONCLUDING REMARKS

And now to review. A systems analysis is an analytic study designed to help a decisionmaker identify a preferred choice among possible alternatives. It is characterized by a systematic and rational approach, with assumptions made explicit, objectives and criteria clearly defined, and alternative courses of action compared in the light of their possible consequences. An effort is made to use quantitative methods, but computers are not essential. What is essential is a model that enables expert intuition and judgment to be applied efficiently. The method provides its answers by processes that are accessible to critical examination, capable of duplication by others, and, more or less, readily modified as new information becomes available. And, in contrast to other aids to decisionmaking, which share the same limitations, it extracts everything possible from scientific methods, and its

*See, for example, Olaf Helmer, Social Technology, The RAND Corporation, P-3063; presented at the Futuribles Conference in Paris, April 1965.

virtues are the virtues of those methods. At its narrowest, systems analysis offers a way to choose the numerical quantities related to a weapon system so that they are logically consistent with each other, with an assumed objective, and with the calculator's expectation of the future. At its broadest, it can help guide national policy. But, even within the Department of Defense, its capabilities have yet to be fully exploited.

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10. ABSTRACT A discussion of the need for: (1) an application of analytic techniques to military problems; and (2) an understanding of these techniques by military officers. The Memorandum defines systems analysis, describes its essential features, illustrates the process of analysis, points out its virtues and limitations, and concludes with remarks about its future.	11. KEY WORDS Military planning Security Strategy Defense Systems analysis